charged current on longitudinally polarised nucleons at an EIC
Overview

- Charged current DIS with polarised nucleons
- CC DIS and electron-ion collider (EIC)
- Event simulation with radiative corrections
- Detector effects and kinematic reconstruction
- Asymmetry results

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Both allow **flavour separation**

CC differs in:
- no **fragmentation functions**
- accesses higher $Q^2$
- different flavour combinations

Want to do both because they
- offer **complementary information**
- access different **kinematic regimes**
SIDIS vs. charged current DIS

- Both allow **flavour separation**
- CC differs in:
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Structure functions

\[
\frac{d^2 \Delta \sigma^{W,-,N}}{dx dy} = \frac{2 \pi \alpha_{em}^2}{xyQ^2} \eta \left[ 2Y_+ x g_1^{W,-,N} - Y_+ g_4^{W,-,N} + y^2 g_L^{W,-,N} \right]
\]

where

\[
g_L \equiv g_4 - 2xg_5
\]

CC structure functions

\[
g_1^{W,-,p}(x) = \Delta u(x) + \Delta \bar{d}(x) + \Delta c(x) + \Delta \bar{s}(x),
\]

\[
g_5^{W,-,p}(x) = -\Delta u(x) + \Delta \bar{d}(x) - \Delta c(x) + \Delta \bar{s}(x)
\]

NLO corrections are modest

- How can we measure polarised CC DIS?
  - need a **new machine**

![Graph showing proton and neutron structure functions with NLO corrections and DSSV predictions.](image)
Charged current DIS at an EIC
Electron-Ion Collider (EIC)

- High energy **electron-hadron** collider
- Assume **eRHIC** baseline performance here
  - Beams: $p^\uparrow$, “$n^\uparrow$” (He$^3$) & nuclei
  - 10-20 GeV **electrons**
  - up to 250 GeV **protons**
  - luminosity: $\sim 10^{33}$ cm$^{-2}$ s$^{-1}$

Use **10 fb$^{-1}$** (~ 1 year of running) as a realistic “chunk” of data for our study

See talks by E. Aschenauer & JH Lee & P. Nadel-Turonski
High energy electron-hadron collider

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Electron Ion Collider: The Next QCD Frontier

Understanding the glue that binds us all
CC DIS cross section

EIC energies

\[ \sigma^{CC} \ [\text{pb}] \]
NLO, \( 0.01 \leq y \leq 0.95 \)

\[ Q_{\text{min}}^2 \ [\text{GeV}^2] \]

\( \sigma \) depends little on \( Q_{\text{min}}^2 \) for \( Q_{\text{min}}^2 < M_W^2 \)

Still feasible at lower electron energy

\[ Q^2 \frac{d\sigma^{CC}}{dQ^2} \ [\text{pb}] \]
NLO, \( 0.01 \leq y \leq 0.95 \)

20 \times 250 \text{ GeV}:
- \( e^+p \)
- \( e^-n \)

10 \times 250 \text{ GeV}:
- \( e^+p \)
- \( e^-n \)

\( n \sim 2x \) lower than \( p \)
\( u(x) < d(x) \)
Kinematic coverage

Higher energy better for
- cross section and
- kinematic reach

Most $\sigma > 100 \text{ GeV}^2$

Limit ourselves to here for this study

Up to $x100$ range in $Q^2$ at given $x$ → QCD evolution
Event simulation with radiative corrections
DJANGOH

- **DIS event generator**
  - includes QED and QCD radiative effects
  - LUND string fragmentation: full final state

- Widely used at HERA
- This analysis uses a new version
  - Add **polarised nucleons**


http://wwwthep.physik.uni-mainz.de/~hspiesb/djangoh/djangoh.html
Radiative corrections

\[ r_\sigma = d^2 \sigma^{W^-, p}_{\mathcal{O}(\alpha^3_{em})} / d^2 \sigma^{W^-, p}_{\mathcal{O}(\alpha^2_{em})} - 1 \]

\[ r_A = A^W_{L, p} \left| \mathcal{O}(\alpha^3_{em}) / A^W_{L, p} \right|_\mathcal{O}(\alpha^2_{em}) - 1 \]

Can expect to be important at low \( x \) where \( A^W_L \) is small.
Detector effects and kinematic reconstruction
Jacquet-Blondel method
Jacquet-Blondel method

Reconstruct kinematics from hadronic final state

\[ y_{JB} = \frac{\sum_i (E_i - p_{z,i})}{2E_e} \]

\[ Q^2_{JB} = \frac{p_{T,h}^2}{1 - y_{JB}} \]

\[ x_{JB} = \frac{Q^2_{JB}}{y_{JB} S} \]

(\( p_{T,h} = |\sum_i \tilde{p}_T,i| \))

Requires sufficient detector resolution and acceptance

- How well can we do with an EIC?
Geant4 simulation of eRHIC detector
High resolution tracking detector is vital

See talk by A. Kiselev

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Geant4 simulation of eRHIC detector

eRHIC detector simulation
Detector performance

- ECal: $\sigma_E/E = 12\% / \sqrt{E}$, $-1 < \eta < 4.5$
- ECal: $\sigma_E/E = 1.8\% / \sqrt{E}$, $-4.5 < \eta < -1$
- HCal: $\sigma_E/E = 38\% / \sqrt{E}$, $2 < \eta < 4.5$

Smear Monte Carlo events with these parameterisations

Better ECal in electron-going direction
Kinematic reconstruction

\[ y_{JB} = \frac{\sum_i (E_i - p_{z,i})}{2E_e} \]

\[ x_{JB} = \frac{Q^2_{JB}}{y_{JB} S} \]

\[ Q^2_{JB} = \frac{p^2_{T,h}}{1 - y_{JB}}, \quad p_{T,h} = |\sum_i \vec{p}_{T,i}| \]

\[ \frac{N_{gen} - N_{out}}{N_{gen} - N_{out} + N_{in}} \]

Kinematic construction
under control
Asymmetry results
Large $A_L^W$ at large $x \sim 80\%$

NLO effects small

$\sigma(A_L^W)/A_L^W$ small

- $<\sim 5\%$ for $p$
- $<\sim 8\%$ for $n$
- $\sim 25\%$ at $x$ limits

Sensitive to “helicity retention”
Impact on global analyses

- Constrain $u$, $d$ & anti-$q$ helicities

- Flavour constraint independent of fragmentation

- Important cross check on SIDIS

  ▶ low $Q^2$, higher twist effects
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Summary

- **Large $A_{LW}$** in CC DIS
  - yields information complementary to SIDIS
- **EIC** is **ideal laboratory** to study it
  - Proposed detector is **well suited** to the measurement
- Similar studies may give insights into:
  - **Unpolarised PDFs** at high $x$ & high $Q^2$
  - **Strangeness**, using CC SIDIS with charm